

DIAMOND, INDUSTRIAL

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Diamond is best known as a gemstone, but some of its unique properties make it ideal for many industrial and research applications as well. Current information on gem-grade diamond can be found in the U.S. Geological Survey (USGS) Minerals Yearbook chapter on gemstones. Diamond that does not meet gem-quality standards for clarity, color, shape, or size is used as industrial-grade diamond. Production and consumption quantities and values reported are estimated in order to avoid disclosing company proprietary data and still provide useful data on the overall market. Trade data in this report are from the U.S. Census Bureau. Quantities are reported in carats unless otherwise noted. All percentages in the report were computed using unrounded data.

Diamond is the hardest known material and has the highest thermal conductivity of any material at room temperature. Diamond is more than twice as hard as its nearest competitors, cubic boron nitride and silicon nitride (Ravi, 1994, p. 537). Because it is the hardest substance known, diamond has been used for centuries as an abrasive in cutting, drilling, grinding, and polishing. Industrial-grade diamond continues to be used as an abrasive for many applications. Even though it has a higher unit cost, diamond has proven to be more cost-effective in many industrial processes because it cuts faster and lasts longer than alternative abrasive materials (Boucher, 1997, p. 26.6). Diamond also has chemical, electrical, optical, and thermal characteristics that make it the best material available to industry for wear- and corrosion-resistant coatings, special lenses, heat sinks in electrical circuits, wire drawing, computing, and other advanced technologies.

Both synthetic and natural diamond have industrial uses. Synthetic industrial diamond is superior to its natural diamond counterpart because its properties can be tailored to specific applications, and it can be produced in large quantities (Boucher, 1996). It is for these reasons that manufactured diamond accounts for more than 80% of the industrial diamond used in the United States and the world.

Legislation and Government Programs

Congress has authorized the sale of all diamond in the National Defense Stockpile (NDS), which is managed by the U.S. Department of Defense (DOD). A portion of the stockpiled diamond stones was scheduled for sale in the NDS 2003 annual plan. During 2003, the Defense National Stockpile Center (DNSC) sold about 0.40 million carats of diamond stone valued at approximately \$18.70 per carat. At yearend 2003, the DNSC reported an NDS remaining inventory of 0.5 million carats of industrial diamond stone, with a market value of \$5.54 million (Mory, 2003). The DOD plans to conduct additional sales until all NDS diamond stone stocks are sold. Further NDS information is available in the “Prices” section.

Production

The USGS conducts an annual survey of domestic industrial diamond producers and U.S. firms that recover diamond wastes. Although most of these companies responded to the 2003 survey, one of the two U.S. primary producers of industrial diamond and one of the four industrial diamond recycling firms withheld data from the survey that they deemed proprietary. Thus, only estimates of U.S. primary and secondary output are provided in this review.

As one of the world’s leading producers of synthetic industrial diamond, the United States accounted for an estimated output of 236 million carats in 2003. Only two U.S. companies produced synthetic industrial diamond during the year—Mypodiamond, Inc., Smithfield, PA, and GE Superabrasives, Worthington, OH. General Electric Co., Fairfield, CT, which owns GE Superabrasives and other diamond manufacturing plants abroad, is one of the world’s largest producers of industrial diamond.

In 2003, nine firms also manufactured polycrystalline diamond (PCD) from synthetic diamond grit and powder. These companies were Dennis Tool Co., Houston, TX; GE Superabrasives, Worthington, OH; Novatek Inc., Provo, UT; Phoenix Crystal Corp., Ann Arbor, MI; Precorp Inc., Provo, UT; SII Megadiamond Industries Inc., Provo, UT; Tempo Technology Corp., Somerset, NJ; U.S. Synthetics Corp., Orem, UT; and Western Diamond Products, Salt Lake City, UT.

It is estimated that about 4.9 million carats of used industrial diamond was recycled in the United States during 2003. Most of this material was recovered by recycling firms from used diamond drill bits, diamond tools, and other diamond-containing wastes. Additional diamond was recovered during the year from residues generated in the manufacture of PCD; most of this material was recovered from within the production operations of the PCD-producing companies.

The recovery and sale of industrial diamond was the principal business of four U.S. companies in 2003—Industrial Diamond Laboratory Inc., Bronx, NY; Industrial Diamond Powders Co., Pittsburgh, PA; International Diamond Services Inc., Houston, TX; and National Research Co., Fraser, MI. In addition to these companies, other domestic firms may have recovered industrial diamond in smaller secondary operations.

Consumption

The United States remained the world's largest market for industrial diamond in 2003. Based on production estimates, trade data, and adjustments for Government stockpile sales, the apparent U.S. consumption of industrial diamond during the year increased to an estimated 423 million carats. The major consuming industries of industrial diamond in the United States during 2003 were construction, machinery manufacturing, mining services (drilling), stone cutting/polishing, and transportation systems (infrastructure and vehicles). Within these sectors, stone cutting and highway building/repair together made up the largest demand for industrial diamond. The manufacture of every automobile made in the United States consumes 1.5 carats of industrial diamond. Research and high-technology uses included close-tolerance machining of ceramic parts for the aerospace industry, heat sinks in electronic circuits, lenses for laser radiation equipment, and polishing silicon wafers and disks drives in the computer industry (Bailey and Bex, 1995).

Diamond tools have numerous industrial functions. Diamond drilling bits and reaming shells are used principally for gas, mineral, and oil exploration. Other applications of diamond bits and reaming shells include foundation testing, masonry drilling, and inspecting concrete. The primary uses of point diamond tools are for dressing and truing grinding wheels and for boring, cutting, finishing, and machining applications. Beveling glass for automobile windows is another application. Cutting dimension stone and cutting/grooving concrete in highway reconditioning are the main uses of diamond saws; other applications include cutting composites and forming refractory shapes for furnace linings. Very fine diamond saws are used to slice brittle metals and crystals into thin wafers for electronic and electrical devices. Diamond wire dies are essential for high-speed drawing of fine wire, especially from hard, high-strength metals and alloys. The primary uses of diamond grinding wheels include edging plate glass, grinding dies, grinding parts for optical instruments, and sharpening and shaping carbide machine tool tips.

Two types of natural diamond are used by industry—diamond stone (generally larger than 60 mesh/250 microns) and diamond bort (smaller, fragmented material). Diamond stone is utilized mainly in drilling bits and reaming shells used by mining companies; it also is incorporated in single- or multiple-point diamond tools, diamond saws, diamond wheels, and diamond wire dies. Diamond bort is used for drilling bits and as a loose grain abrasive for polishing. Other tools that incorporate natural diamond include bearings, engraving points, glass cutters, and surgical instruments.

Synthetic diamond grit and powder are used in diamond grinding wheels, saws, impregnated bits and tools, and as a loose abrasive for polishing. Diamond grinding wheels can be as much as 1 meter in diameter.

Loose powders made with synthetic diamond for polishing are used primarily to finish cutting tools, gemstones, jewel bearings, optical surfaces, silicon wafers, and wiredrawing dies for computer chips. Hundreds of other products made from ceramics, glass, metals, and plastics also are finished with diamond powders.

The use of polycrystalline diamond shapes (PDSs) and polycrystalline diamond compacts (PDCs) continues to increase for many of the applications cited above, including some of those that employ natural diamond. The use of PDSs, PDCs, and matrix-set synthetic diamond grit for drilling bits and reaming shells has increased in recent years. PDSs and PDCs are used in the manufacture of single- and multiple-point tools, and PDCs are used in a majority of the diamond wire-drawing dies.

Prices

Natural and synthetic industrial diamonds differ significantly in price (Boucher, 1997, p. 26.6). Natural industrial diamond normally has a more limited range of values. Its price varies from about \$0.30 per carat for bort-size material to about \$7 to \$10 per carat for most stones, with some larger stones selling for up to \$200 per carat.

Synthetic industrial diamond has a much larger price range than natural diamond. Prices of synthetic diamond vary according to particle strength, size, shape, crystallinity, and the absence or presence of metal coatings. In general, synthetic diamond prices for grinding and polishing range from as low as \$0.40 to \$1.50 per carat. Strong and blocky material for sawing and drilling sells for \$1.50 to \$3.50 per carat. Large synthetic crystals with excellent structure for specific applications sell for many hundreds of dollars per carat (Law-West, 2002, p. 23.8).

In 2003, the DNSC awarded bids that ranged from \$11.37 to \$56.55 per carat for NDS diamond stone sold, with the average awarded bid being \$18.70 per carat (Mory, 2003).

Foreign Trade

The United States continued to lead the world in industrial diamond trade in 2003; imports were received from 40 countries, exports were sent to 46 countries, and reexports were sent to 38 countries (tables 1-4). Although the United States has been a major producer of synthetic diamond for decades, growing domestic markets have become more reliant on foreign sources of industrial diamond in recent years. U.S. markets for natural industrial diamond always have been dependent on imports and secondary recovery operations because there has been no domestic production of natural diamond.

During 2003, U.S. imports of industrial-quality diamond stones (natural and synthetic) decreased by 11% from 2002 to about 1.82 million carats valued at more than \$5.63 million (table 1). Imports of diamond powder, dust, and grit (natural and synthetic) increased by 35% from 2002 to 250 million carats valued at almost \$65 million (table 2).

Reexports may account for a significant portion of total exports/reexports; therefore, exports and reexports are listed separately in tables 3 and 4 so that U.S. trade and consumption can be calculated more accurately. During 2003, U.S. exports of industrial diamond stones decreased by almost 71% from 2002 to 0.34 million carats valued at \$1.92 million, and U.S. reexports of industrial diamond

stone increased by approximately 84% from 2002 to 2.37 million carats valued at \$21.1 million (table 3). U.S. exports of industrial diamond powder, dust, and grit (natural and synthetic) decreased by 10% from 2002 to 73.9 million carats valued at \$43.1 million, and reexports of industrial diamond powder, dust, and grit (natural and synthetic) decreased by 7% from 2002 to 7.24 million carats valued at \$3.66 million (table 4).

Industry Structure

Total 2003 industrial diamond output worldwide was estimated by USGS to be in excess of 612 million carats valued between \$612 million and \$1 billion. World consumption of industrial diamond in the 1990s had been increasing at rates of more than 10% per year (Boucher, 1997, p. 26.6).

In 2003, industrial diamond was produced in 31 countries (tables 5, 6). In addition to the countries listed in table 6, Germany and the Republic of Korea produced synthetic diamond, but specific data on their output could not be confirmed. China may have produced more than the output listed in the table (Wilson Born, National Research Co., oral commun., 2003).

In 2003, more than 77% of the total global natural and synthetic industrial diamond output was produced in Australia, Ireland, Russia, South Africa, and the United States. The dominance of synthetic diamond over natural diamond was even more pronounced, as synthetic diamond accounted for nearly 89% of global production and consumption.

The Ekati Diamond Mine, Canada's first operating commercial diamond mine, completed its fifth full year of production. In 2003, Ekati produced 5.57 million carats of diamond from 4.46 million metric tons (Mt) of ore (BHP Billiton Ltd., 2004b). BHP Billiton Ltd. has an 80% controlling ownership in the Ekati mine, which is located in the Northwest Territories in Canada. Ekati has estimated its reserves to be 60.3 Mt of ore in kimberlite pipes that contain 54.3 million carats of diamond, and Ekati projects the mine life to be 25 years. Ekati diamonds are sold by BHP's Antwerp sales office. The Ekati mine is now producing from the Koala, Panda, and Misery kimberlite pipes. In November 2002, BHP Billiton began using underground mining techniques to recover diamonds from deeper portions of the Koala kimberlite pipe, which was initially mined by open pit methods (Diamond Registry Bulletin, 2002). Plans have now been approved for underground mining of deeper portions of the adjacent Panda kimberlite pipe, and initial production is expected in early 2005 (BHP Billiton Ltd., 2004a). Approximately one-third of the Ekati diamond production is industrial-grade material (Darren Dyck, senior project geologist, BHP Diamonds, Inc., oral commun., May 27, 2001).

The Diavik Diamond Mine, also in the Northwest Territories, has estimated its reserves to be 25.6 Mt of ore in kimberlite pipes, containing 107 million carats of diamond. Diavik projects the mine life to be from 16 to 22 years. Diavik is an unincorporated joint venture between Diavik Diamond Mines Inc. (60%) and Aber Diamond Mines Ltd. (40%). The Diavik mine began diamond production in December 2002 and reached full production in February 2003—60 days ahead of the projected opening date (Professional Jeweler, 2002¹). In 2003, Diavik produced 3.8 million carats of diamond from 1.3 Mt of ore. The mine is expected to produce about 107 million carats of diamond at a rate of 8 million carats per year worth about \$63 per carat (Diavik Diamond Mines Inc., 2000, p. 10-12; 2004).

A third Canadian commercial diamond project in the Northwest Territories is the Snap Lake diamond project. De Beers Canada Mining Inc. has projected that Snap Lake would begin production in 2006 or 2007 (Law-West, 2002). The Snap Lake diamond project estimates its reserves to be about 23 Mt of ore in a kimberlite dike that contain about 39 million carats of diamond. The mine life is projected to be 20 years or more (J.T. Haynes, assistant site manager, De Beers Canada Mining Inc., oral commun., 2001).

Diamond exploration is continuing in Canada, and many new deposits have been found. There are several other commercial diamond projects and additional discoveries located in Alberta, British Columbia, the Northwest Territories, Nunavut, Ontario, and Quebec. Canada produced about 15% of the world's diamond in 2003, and Canada outranked many of the world's major diamond-mining countries in price per carat of diamonds produced (Diamond Registry Bulletin, 2004a). If Canadian production continues to increase at about the same rate, Canada will probably eclipse South Africa's diamond production within a decade.

Near the end of 2003, De Beers and the U.S. Department of Justice began work toward settlement of its long-running dispute over alleged illegal price fixing. On July 13, 2004, De Beers Centenary AG pled guilty in Federal court in Ohio to conspiring to fix the price of industrial diamond in the United States and elsewhere, resolving a 1994 case. De Beers was sentenced to pay a \$10 million fine. With this settlement, De Beers is now free to enter the U.S. market (Diamond Registry Bulletin, 2004b, c).

Outlook

The United States will most likely continue to be the world's leading market for industrial diamond well into the next decade. The United States also should remain a significant producer and exporter of industrial diamond. The strength of U.S. demand will depend on the vitality of the Nation's industrial base and on how well the diamond life cycle cost-effectiveness compares with competing materials that initially are less expensive. The many advantages that diamond offers for precision machining and longer tool life, which compensate for increases in other production line costs, seem certain to spur demand for diamond tools. In fact, even the use of wear-resistant diamond coatings to increase the life of materials that compete with diamond is a rapidly growing application. Increased tool life not only leads to lower costs per unit of output but also means fewer tool changes and longer production runs

¹References that include a section mark (§) are found in the Internet References Cited section.

(Advanced Materials & Processes, 1998). In view of the many advantages that come from increased tool life and reports that diamond film surfaces can increase durability by a factor of 50, much wider use of diamond as an engineering material is expected.

The most dramatic increase in U.S. use of industrial diamond is likely to be in the construction sector as the Nation builds and repairs the U.S. highway system in its implementation of the Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2003 (S. 1072, H.R. 2088), which is expected to be enacted during 2004 (U.S. Senate, 2004§). Demand for saw-grade diamond alone is expected to increase in the coming year if goals mandated by the Act for the repair and replacement of roads, bridges, and other components in the transportation infrastructure of the country are fulfilled.

One U.S. company, Apollo Diamond, Inc., developed and patented a method for growing gem-quality diamond by chemical vapor deposition (CVD). The CVD technique transforms carbon into plasma, which then is precipitated onto a substrate as diamond. CVD has been used for more than a decade to cover large surfaces with microscopic diamond crystals, but until now, no one had discovered the combination of temperature, gas composition, and pressure that results in the growth of a single diamond crystal. CVD diamond can be grown for about \$5 per carat. The promise of CVD is that it produces extremely pure crystal. CVD diamond precipitates as nearly 100%-pure diamond and therefore may not be discernible from natural diamond. But the greatest potential for CVD diamond is in computer technology. For diamond to be a practical material for use as a semiconductor, it must be affordably grown in large wafers. CVD growth is limited only by the size of the seed placed in the Apollo Diamond machine. Starting with a square, wafer-like fragment, the Apollo Diamond process will grow the diamond into a prismatic shape, with the top slightly wider than the base. For the past 7 years, Apollo Diamond has been growing increasingly larger seeds by chopping off the top layer of growth and using that as the starting point for the next batch. At the moment, the company is producing 10-millimeter wafers but predicts it will reach about 10 times that in 5 years (Davis, 2003). Scientists have said that diamond computer chips are more durable because they can work at a temperature of up to 1,000° C, while silicon computer chips stop working at about 150° C. This means that diamond computer chips can work at a much higher frequency or faster speed and can be placed in a high-temperature environment (Diamond Registry Bulletin, 2003§).

According to industry sources, PCD for abrasive tools and wear parts will continue to replace competing materials in many industrial applications by providing closer tolerances as well as extending tool life. For example, PDCs and PDSs will continue to displace natural diamond stone and tungsten carbide products used in the drilling and tooling industries (Wilson Born, National Research Co., written commun., 1998).

Truing and dressing applications will remain a major domestic end use for natural industrial diamond stone. Stones for these applications have not yet been manufactured economically. No shortage of the stone is anticipated, however, because new mines and more producers selling in the rough diamond market will maintain ample supplies. More competition introduced by the additional sources also may temper price increases.

World demand for industrial diamond will continue to increase during the next few years. Constant-dollar prices of synthetic diamond products, including chemical-vapor-deposition diamond films, will decline as production technologies become more cost effective and as competition increases from low-cost producers in China and Russia.

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TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES, BY COUNTRY¹

(Thousand carats and thousand dollars)

Country	Natural industrial diamond stones ²				Miners' diamond, natural and synthetic ³			
	2002		2003		2002		2003	
	Quantity	Value ⁴	Quantity	Value ⁴	Quantity	Value ⁴	Quantity	Value ⁴
Australia	4	29	18	240	1	33	(5)	5
Belgium	103	372	126	386	65	453	18	258
Botswana	(5)	12	2	36	80	471	1	44
China	4	7	34	26	--	--	(5)	21
France	(5)	3	--	--	(5)	5	--	--
Ghana	75	177	61	209	163	450	21	275
Guyana	--	--	3	11	56	3,170	(5)	8
India	131	29	37	21	4	40	--	--
Ireland	205	2,910	227	281	259	253	930	633
Namibia	41	148	64	255	--	--	26	75
Netherlands	5	21	--	--	33	645	(5)	11
Russia	7	78	(5)	3	170	387	--	--
Switzerland	2	68	2	28	383	429	(5)	22
United Kingdom	47	140	139	1,720	103	152	5	24
Other	69	645	50	246	38	1,410	59	792
Total	692	4,640	761	3,470	1,360	7,900	1,060	2,170

-- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Includes glazers' and engravers' diamond unset, Harmonized Tariff Schedule of the United States (HTS) codes 7102.21.3000 and 7102.21.4000.

³HTS codes 7102.21.1010 and 7102.21.1020.

⁴Customs value.

⁵Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND POWDER, DUST AND GRIT, BY COUNTRY¹

(Thousand carats and thousand dollars)

Country	Synthetic ²				Natural ²			
	2002		2003		2002		2003	
	Quantity	Value ³	Quantity	Value ³	Quantity	Value ³	Quantity	Value ³
Belgium	3,210	1,010	8,400	3,130	5,030	2,970	2,750	1,470
China	39,800	5,620	68,400	6,750	2,030	208	85	42
Czech Republic	8,170	1,590	7	5	363	204	--	--
Germany	144	42	51	28	2	3	18	9
India	572	177	3,010	638	195	60	82	43
Ireland	63,500	31,700	92,600	34,700	2,090	1,060	1,310	604
Italy	1,630	730	2,130	983	50	13	--	--
Japan	4,530	3,460	5,320	4,870	312	347	32	46
Korea, Republic of	9,360	5,000	7,990	4,080	18	8	96	40
Macau	742	130	130	135	--	--	--	--
Romania	407	89	419	158	5	21	26	28
Russia	10,800	1,370	15,200	1,940	2,310	515	63	18
Switzerland	871	493	908	564	2,380	1,120	284	146
Ukraine	22,100	1,770	29,200	2,040	--	--	--	--
United Kingdom	2,940	857	4,910	1,030	820	334	680	242
Other	738	697	5,770	583	499	321	151	235
Total	169,000	54,700	244,000	61,700	16,100	7,180	5,580	2,920

-- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States codes 7105.10.0020, 7105.10.0030, and 7105.10.0050 for synthetic and 7105.10.0011 and 7105.10.0015 for natural.

³Customs value.

Source: U.S. Census Bureau.

TABLE 3
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND
STONES, BY COUNTRY¹

(Thousand carats and thousand dollars)

Country	Industrial unworked diamonds ²			
	2002		2003	
	Quantity	Value ³	Quantity	Value ³
Exports:				
Australia	2	27	2	19
Belgium	15	146	11	111
Bulgaria	38	56	27	38
Canada	103	341	22	81
Germany	15	114	2	24
Hong Kong	233	2,050	49	487
Japan	294	2,540	41	412
Korea, Republic of	96	990	9	92
Malaysia	31	124	133	316
Mexico	84	418	8	42
Poland	2	18	(4)	3
Thailand	58	585	--	--
Other	169	1,240	32	299
Total	1,140	8,650	336	1,920
Reexports:				
Belgium	611	6,220	700	6,180
Canada	191	584	154	540
Germany	53	460	27	212
Hong Kong	7	75	266	2,640
Ireland	24	162	66	210
Israel	34	262	7	72
Japan	111	1,110	620	6,290
Korea, Republic of	47	481	157	1,710
Mexico	4	35	39	440
Netherlands	44	438	--	--
Switzerland	(4)	5	7	71
United Arab Emirates	80	454	45	247
United Kingdom	64	608	160	1,680
Other	22	217	128	852
Total	1,290	11,100	2,370	21,100
Grand total	2,430	19,800	2,710	23,100

-- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States code 7102.21.0000.

³Customs value.

⁴Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 4
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND POWDER, DUST AND GRIT, BY COUNTRY¹

(Thousand carats and thousand dollars)

Country	Synthetic ²				Natural ²			
	2002		2003		2002		2003	
	Quantity	Value ³	Quantity	Value ³	Quantity	Value ³	Quantity	Value ³
Exports:								
Austria	1,170	685	212	164	53	9	--	--
Belgium	757	473	799	332	118	282	383	266
Brazil	2,350	863	2,830	1,220	38	12	2	6
Canada	2,390	2,100	1,860	1,820	166	121	91	174
France	68	42	113	24	41	42	42	10
Germany	1,020	526	7,060	3,800	640	844	277	187
Greece	317	180	343	151	--	--	--	--
Hong Kong	537	658	1,070	335	314	255	66	63
India	1,680	715	2,000	785	64	79	6	8
Ireland	27,600	20,400	15,000	10,500	20	37	500	480
Israel	374	183	998	265	45	27	554	134
Italy	1,150	481	895	328	248	104	94	37
Japan	14,700	9,530	14,800	7,710	738	1,480	510	673
Korea, Republic of	12,100	5,300	12,700	5,330	397	131	468	148
Macau	746	167	374	168	--	--	--	--
Malaysia	243	273	1,070	736	27	28	20	18
Mexico	407	210	519	245	73	56	169	129
Netherlands	159	222	--	--	387	600	--	--
Philippines	45	56	--	--	--	--	71	57
Singapore	94	113	145	201	11	8	57	93
Spain	252	92	430	111	113	47	115	36
Switzerland	631	489	472	761	4,150	3,980	1,300	2,130
Taiwan	2,210	1,310	2,360	1,060	1,060	144	150	107
Thailand	678	367	1,070	410	64	54	47	51
United Kingdom	138	61	291	179	159	152	93	57
Other	572	481	685	474	524	219	756	1,140
Total	72,400	46,000	68,200	37,100	9,450	8,700	5,770	6,000
Reexports:								
Australia	34	10	18	12	--	--	--	--
Austria	492	158	211	94	73	57	194	43
Belgium	199	53	82	23	--	--	111	47
Brazil	8	10	--	--	8	5	15	8
Canada	1,120	993	512	798	19	25	37	91
France	26	4	--	--	33	9	68	15
Germany	619	292	350	143	117	91	79	26
Hong Kong	38	49	--	--	20	20	--	--
India	30	17	329	94	22	38	--	--
Ireland	244	174	178	143	2	3	4	3
Israel	--	--	--	--	35	11	--	--
Italy	771	282	519	163	11	5	88	22
Japan	32	21	308	110	20	38	119	99
Korea, Republic of	1,770	646	1,950	745	345	230	543	229
Macau	413	83	166	30	--	--	--	--
Malaysia	87	25	--	--	20	4	66	11
Mexico	(4)	3	71	14	7	13	85	112
South Africa	18	3	--	--	2	6	11	3
Spain	55	24	99	27	13	15	55	20
Switzerland	123	67	62	21	--	--	--	--
Taiwan	229	215	329	269	24	40	48	61
United Kingdom	397	183	164	64	59	76	49	26
Other	226	156	307	78	24	16	75	17
Total	6,930	3,470	5,590	2,830	854	701	1,650	833
Grand total	79,400	49,500	73,700	39,900	10,300	9,410	7,410	6,840

-- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States codes 7105.10.0025 for synthetic and 7105.10.0010 for natural.

³Customs value.

⁴Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 5
NATURAL DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY AND TYPE^{1,2,3}

(Thousand carats)

Country and type ⁴	1999	2000	2001	2002	2003
Gemstones:					
Angola	3,360	3,914 ⁵	4,653 ⁵	4,520 ^r	4,770
Australia	13,403 ^{r,5}	11,956 ^{r,5}	11,779 ^{r,5}	15,142 ^{r,5}	14,900
Botswana	17,200	18,500	19,800	21,300	22,800
Brazil	900 ⁵	1,000 ⁵	700 ^{r,5}	500 ^{r,5}	500
Canada	2,429 ⁵	2,534 ^{r,5}	3,716 ^{r,5}	4,984 ⁵	11,200
Central African Republic	311	346	337 ^r	311 ^r	300
China	230	230	235	235	235
Congo (Kinshasa)	4,120	3,500	3,640 ^r	4,400 ^r	5,400
Cote d' Ivoire	270	210	207 ^r	204 ^r	205
Ghana	546	792	936	770	800
Guinea	287	278	273 ^r	368 ^r	368
Guyana	45 ⁵	82 ⁵	179 ⁵	248 ^{r,5}	250
Liberia	120	100	100	48 ^r	36
Namibia	1,630	1,450	1,487 ⁵	1,350	1,650
Russia	11,500	11,600	11,600	11,500	12,000
Sierra Leone	7 ^r	58 ^r	167 ^r	147 ^{r,5}	214
South Africa	4,000	4,320	4,470	4,350	5,070
Tanzania	200	301	216	181 ^r	198
Venezuela	59 ⁵	29 ⁵	14 ⁵	46 ^{r,5}	30
Zimbabwe	15	8	--	--	--
Other ⁶	20	24	25	25	24
Total	60,600 ^r	61,200 ^r	64,500 ^r	70,600 ^r	80,900
Industrial:					
Angola	373	435	517	502 ^r	530
Australia	16,381 ⁵	14,612 ^{r,5}	14,397 ^{r,5}	18,500 ⁵	18,200
Botswana	5,730	6,160	6,600	7,100	7,600
Central African Republic	120	115	112 ^r	104 ^r	100
China	920	920	950	955	955
Congo (Kinshasa)	16,000	14,200	14,560 ^{r,5}	17,456 ^{r,5}	21,600
Cote d' Ivoire	128	110	102 ^r	102 ^r	102
Ghana	136	198	234	193	200
Guinea	96	91	91 ^r	123 ^r	123
Liberia	80	70	70	32 ^r	24
Namibia	--	106	--	--	--
Russia	11,500	11,600	11,600	11,500	12,000
Sierra Leone	2 ^r	19 ^r	56 ^r	205 ^{r,5}	296
South Africa	6,010	6,470	6,700	6,530	7,600
Tanzania	35 ⁵	53 ⁵	38 ⁵	32 ^{r,5}	35
Venezuela	36 ⁵	80 ⁵	28 ^{r,5}	61 ^{r,5}	50
Zimbabwe	30	15	--	--	--
Other ⁷	52	64	66	68	67
Total	57,600 ^r	55,300 ^r	56,100 ^r	63,500 ^r	69,500
Grand total	118,000 ^r	117,000	121,000 ^r	134,000 ^r	150,000

^rRevised. -- Zero.

¹World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Table includes data available through June 10, 2004.

³In addition to the countries listed, Nigeria and the Republic of Korea produce natural diamond and synthetic diamond, respectively, but information is inadequate to formulate reliable estimates of output levels.

⁴Includes near-gem and cheap-gem qualities.

⁵Reported figure.

⁶Includes Gabon, India, and Indonesia.

⁷Includes India and Indonesia.

TABLE 6
SYNTHETIC DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY^{1, 2, 3}

(Thousand carats)

Country	1999	2000	2001	2002	2003
Belarus	25,000	25,000	25,000	25,000	25,000
China	16,500	16,800	17,000	17,000	17,000
Czech Republic	3,000	--	--	--	--
France	3,000	3,000	3,000	3,000	3,000
Greece	750	750	--	--	--
Ireland	60,000	60,000	60,000	60,000	60,000
Japan	32,000	33,000	33,000	34,000	34,000
Poland	200 ⁴	--	--	--	--
Romania	3,000 ⁴	--	--	--	--
Russia	80,000	80,000	80,000	80,000	80,000
Slovakia	3,000 ⁴	--	--	--	--
South Africa	--	--	60,000	60,000	60,000
Sweden	25,000	20,000	20,000	20,000	20,000
Ukraine	8,000	8,000	8,000	8,000	8,000
United States	161,000	182,000	202,000	222,000	236,000
Total	420,000	429,000	508,000	529,000	543,000

-- Zero.

¹World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Table includes data available through June 10, 2004.

³In addition to the countries listed, the Republic of Korea also produces significant amounts of synthetic diamond, but output is not officially reported, and available information is inadequate to formulate reliable estimates of output levels.

⁴Reported figure.